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EVAPORATIVE COOLING OF MEN IN WET CLOTHING

by

F. N. Craig

March 1972

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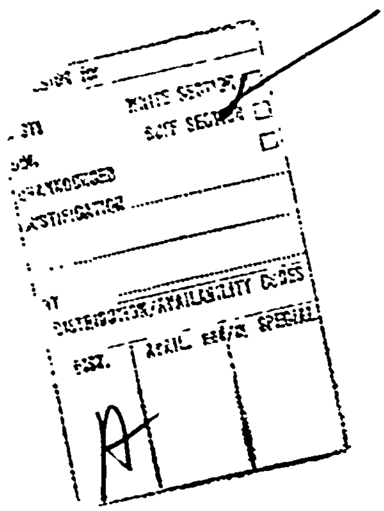

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Three groups of men wearing the CBR protective uniform were exposed to six conditions of varying heat, humidity, wind, exercise, and initial water content of the clothing. Each condition was repeated with and without a 2-mg dose of atropine sulfate. In troops wearing the CBR protective uniform who inject a 2-mg dose of atropine into themselves on the mistaken assumption of an exposure to an anticholinesterase agent, the rise in rectal temperature caused by the inhibition of sweating by atropine can be kept within safe limits if exercise is avoided and the clothing is wet with sweat at the time of injection. In environments where sweat does not accumulate in the clothing, artificial wetting of the clothing would be required to compensate for the deficit in sweating. In environments where sweat does not accumulate in the clothing, the deficit in evaporative heat loss associated with atropine is matched by an approximately equal gain in storage of heat in the body. When the clothing is wetted artificially or by the accumulation of sweat, the heat storage is not affected by the deficit in evaporative heat loss; thus, an increment in evaporation from wet clothing is less efficient in cooling the body than evaporation from the skin under dry clothing. Sweating (nude weight loss) and evaporation from clothing (clothed weight loss) increase in proportion one to the other, but the fraction of sweat evaporated is less from wet than from dry clothing. Sweat production during exposure to heat is substantially less when the clothing is initially wet with water. The reduction in sweating is attributed to the cooling of the skin by the wet clothing.

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Medical Research Division

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Task 1W662710AD2501

DEPARTMENT OF THE ARMY
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Biomedical Laboratory
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FOREWORD

The work described in this report was authorized under Task 1W662710AD2501, Medical Defense Against Chemical Agents, Biomedical Evaluation of Protective Materiel. The data were collected in July and August 1970, March and April 1971, and July and August 1971.

The volunteers in these tests are enlisted US Army personnel. These tests are governed by the principles, policies, and rules for medical volunteers as established in AR 70-25.

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DIGEST

Three groups of men wearing the CBR protective uniform were exposed to six conditions of varying heat, humidity, wind, exercise, and initial water content of the clothing. Each condition was repeated with and without a 2-mg dose of atropine sulfate. The conclusions follow.

In troops wearing the CBR protective uniform who inject a 2-mg dose of atropine into themselves on the mistaken assumption of an exposure to an anticholinesterase agent, the rise in rectal temperature caused by the inhibition of sweating by atropine can be kept within safe limits if exercise is avoided and the clothing is wet with sweat at the time of injection. In environments where sweat does not accumulate in the clothing, artificial wetting of the clothing would be required to compensate for the deficit in sweating.

In environments where sweat does not accumulate in the clothing, the deficit in evaporative heat loss associated with atropine is matched by an approximately equal gain in storage of heat in the body. When the clothing is wetted artificially or by the accumulation of sweat, the heat storage is not affected by the deficit in evaporative heat loss; thus, an increment in evaporation from wet clothing is less efficient in cooling the body than evaporation from the skin under dry clothing.

Sweating (nude weight loss) and evaporation from clothing (clothed weight loss) increase in proportion one to the other, but the fraction of sweat evaporated is less from wet than from dry clothing.

Sweat production during exposure to heat is substantially less when the clothing is initially wet with water. The reduction in sweating is attributed to the cooling of the skin by the wet clothing.

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EVAPORATIVE COOLING OF MEN IN WET CLOTHING

I. INTRODUCTION.

In an assessment of CBR protective uniforms during an amphibious assault in a tropical environment, protected units suffered a large proportion of heat casualties.[1] The authors called attention to the dangers of the unsupervised use of atropine by combat troops who suspect they are under attack by anticholinesterase agents. They state that although the "nerve gas" victim will be improved by the administration of atropine, a victim actually suffering from impending heat exhaustion might well be pushed into heat stroke by administration of the same drug because of its inhibition of sweating.

In a cool climate, protected troops given a 6-mg dose of atropine sulfate were able to perform routine military tasks without impairment of temperature regulation if hard work were avoided.[2] However, in a warm temperate environment in unprotected troops given a 2-mg dose, elevation in rectal temperature prevented 15 of 20 men from completing a 2-hour march.[3] In nude resting men given a 2-mg dose of atropine, sweating returned to the pre-atropine rate within about half an hour, although the rectal temperature remained elevated for another 2 hours.[4] With larger doses a prolonged shutdown of sweating has been obtained.[5]

In protected men, the effect of inhibition of sweating may be moderated by the presence of sweat already accumulated in the clothing. In sun or shade after walking for 2 hours at 30°C, the protective assembly may contain about a kilogram of sweat.[6] This raises the question of just how serious a threat atropine poses to the thermal state of men in the protective uniform. Although eventually a 6-mg dose should be tested, the dose in the present experiments was limited to 2 mg. The objective was to observe body temperatures at rest and in a short period of exercise in a series of environmental conditions with increasing heat stress. Although the suspected chemical casualty should remain at rest, the tactical situation might require some movement. The exercise was included to cover this contingency and also to produce a substantial increase in body temperature within safe limits. Because of the insulation of the clothing, evaporation of water from clothing may be less effective in cooling the body than evaporation from the bare skin.[7,8] The efficiency of evaporative cooling in the clothed man has not been measured.[9] Accurate assessment of the heat exchange between man and environment is difficult enough under equilibrium conditions and has

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[1] Yarger, W. E., Schwartz, P. L., and Goldman, R. F. An Assessment of CBR Protective Uniforms During An Amphibious Assault in a Tropical Environment: Heat Stress Study 69-10. US Naval Medical Field Research Laboratory, Camp Lejeune, North Carolina. November 1969. UNCLASSIFIED Report.

[2] Moylan-Jones, R. J. The Effect of a Large Dose of Atropine Upon the Performance of Routine Tasks. Brit. J. Pharmacol. *37*, 301-305 (1969).

[3] Robinson, S. MLCR 15. Indiana University. The Physiological Effects of Atropine and Potential Atropine Substitutes. August 1953. UNCLASSIFIED Report.

[4] Craig, F. N., and Cummings, E. G. Speed of Action of Atropine On Sweating. J. Appl. Physiol. *20*, 311-315 (1965).

[5] Webb, P., Garlington, L. N., and Schwarz, M. J. Insensible Weight Loss at High Skin Temperatures. J Appl. Physiol. *11*, 41-44 (1957).

[6] Craig, F. N., Cummings, E. G., and Bales, P. D. CRDLR 3101. Contribution of the E33 Hood to Heat Stress on Men Wearing CBR Protective Clothing. December 1961. UNCLASSIFIED Report.

[7] Burton, A. C. An Analysis of the Physiological Effects of Clothing in Hot Environments. National Research Council, Canada. Report 186. 24 November 1944.

[8] Burton, A. C., and Edholm, O. G. Man in a Cold Environment. Arnold, London, England. 1955.

[9] Nishi, Y., and Gagge, A. P. Moisture Permeation of Clothing–A Factor Governing Thermal Equilibrium and Comfort. No. 2135. American Society of Heating, Refrigerating and Air-Conditioning Engineers Transactions 76, 137-145 (1970).

not been attempted under the unsteady states in the present experiments. However, the heat storage during exercise should vary inversely with the evaporative cooling when other conditions are held constant. From the changes in heat storage, it is hoped to obtain a measure of the efficiency of evaporative cooling from wet clothing.

II. METHODS.

The experiments were conducted according to the recommendations of the Declaration of Helsinki. The subjects were 13 enlisted men of the US Army who volunteered (table I). The clothing assembly is described in table II. The jacket was tucked into the trousers, the trouser legs into the boots, and the jacket arms into the gloves. This arrangement prevented dripping of sweat. The mask and hood collected much of the sweat from the head region; it ran down and was absorbed in the clothing. Some of the thermal characteristics of the assembly have been described.[10] The clothing was laundered before each wearing. The four items of fatigues and underwear on one occasion weighed 3890 grams after washing, 3385 grams after 15 minutes in the dryer, 2915 grams after hanging for 3 hours at temperatures of 30°C dry bulb and 26°C wet bulb, 1965 grams dried, and 2065 grams after hanging for 3 hours at the same temperature.

The men were weighed nude and clothed before and after each test and clothed at 30-minute intervals during the test. The weights were corrected for water intake. The M17A1 mask can be connected to the canteen to permit drinking without disturbing the mask. Water at room temperature was supplied after the 60th minute. An L & N Speedomax recorder printed the individual skin temperature, the average skin temperature, and the rectal temperature, readable to 0.1°F, at intervals of 60 seconds. The rectal thermocouple was placed at a depth of 7.5 cm. Skin temperature is reported as the average of readings on the chest, shoulder, hip, and thigh.

Table I. Subjects

Series	Subjects		Age	Weight	Height
			yr	*kg*	*cm*
1	A	5907	27	67	165
1	B	5931	25	87	167
1	C[a]	5899	22	87	173
1	D	5912	23	66	174
2,4	E[a]	6111	23	97	188
2,4	F	6117	20	82	181
2,4	G	6113	22	68	181
2,4	H	6095	25	82	183
3,5,6	I	6184	23	70	172
3,6	J[b]	6194	20	72	187
3,5,6	K	6229	22	65	170
3,5,6	L	6225	24	65	182
5	M	6224	20	63	163

[a]Treadmill at 5%.
[b]Walked intermittently at 10% in series 3.

Table II. Clothing Assembly

Item	Weight
	gm
Wool socks	75
Undershirt, 1/2 cotton, 1/2 wool	430
Underwear, 1/2 cotton, 1/2 wool	450
Fatigue jacket, sateen	650
Fatigue trousers, sateen	640
Gloves, cotton	100
Boots	1700
M17A1 protective mask and hood	1060
Electrodes, thermocouples, and leads	2165

[10]Craig, F. N., and Cummings, E. G. Thermal Influence of Sunshine and Clothing on Men Walking in Humid Heat. J. Appl. Physiol. *17*, 311-316 (1962).

A 3- by 3-cm plastic cup was attached to the volar surface of the forearm. Dry gas (98.5% O_2, 1.5% N_2, an excess supply) from a compressed gas cylinder was passed through the cup at rates of from 0.2 to 1.0 liter per minute; the relative humidity of the outflowing air was recorded by a series of lithium chloride sensors (Aminco). The production of sweat under the cup was calculated at 10-minute intervals from the relative humidity, the airflow, and the water content of air saturated at the temperature of the sensors, which were kept in the hot room.

The sides of the treadmill were enclosed from the floor to the ceiling with transparent plastic to make an open-ended wind tunnel 4.5 feet wide, 7.5 feet high, and 12 feet long. The subject either walked up a 10% grade at 3 mph (1.35 m/sec) or reclined on a plastic mesh deck chair facing an airflow of either 1.35 or 0.05 m/sec. The various environmental conditions are listed in table III.

The men were tested at weekly intervals to minimize changes in acclimatization. They walked from the 35th to the 60th minute in series 1, 2, 3, 4, and 6, and from the 185th to the 210th minute in series 1. In the tests with atropine sulfate, a dose of 28.5 μg/kg (about 2 mg per man) was injected intravenously at the 20th minute. In series 4, the fatigues and underwear were wet initially with about 1 kg of water. In series 6, only the underwear was initially wet with about 1 kg of water. The shifts in average weight among the items of clothing in series 3, 5, and 6 are shown in table IV. The individual items were not weighed in series 4.

Heat storage was calculated from the sum of one-third the change in average skin temperature and two-thirds the change in rectal temperature, the nude weight, the specific heat of 0.83 cal/gm, and the DuBois surface area. The heat of evaporation was calculated from the clothed weight loss, the same surface area, and a latent heat of 580 cal/gm. Units of calories per square meter per hour were converted to watts per square meter by the factor 1.163.

III. RESULTS.

Average results for each condition are shown in figures 1, 2, and 3. The exercise produced rapid increases in body temperature and sweat rate, which provided a test of the mechanisms for eliminating heat from the body. The dissipation during rest of the heat stored during exercise was a rather slow process under these conditions. Typical effects of atropine are seen in the acceleration of the heart at 30 minutes (that is, 10 minutes after injection and 5 minutes before the beginning of exercise) and in the delay in the increase in sweating at the beginning of exercise.

The deficit in sweat production led to a distinct increase in rectal temperature in the dry conditions (series 1, 2, and 5), but not in the humid conditions (series 3, 4, and 6). The beneficial effect of initial wetting of the suit was most apparent in series 6, whereas in the high humidity conditions, there was as little effect of atropine on rectal temperature in series 3 when the clothing was initially dry as in a series 4 when the clothing was initially wet. The rate of sweating and the skin temperature in the half hour before exercise were greater in series 3 than in the less humid condition in series 2.

The changes in body temperature, sweating, clothed weight loss, and heart rate in figures 1, 2, and 3 were what might be expected under these conditions. In each environment, the experiments with and without atropine provided a range of nude and clothed weight losses, although the range of the latter was small. The clothed weight loss for the whole exposure increased significantly with the nude weight loss in all the conditions except series 4; the fraction evaporated was greatest in series 1 and 2 (figure 4 and table V).

The relation between evaporative cooling (E) and heat storage (S) is shown in figures 5, 6, and 7 and table VI in each series for two periods: first, the 30- to 60-minute period including the walk in all but series 5; and second, the 90- to 180-minute period at rest. In the 30- to 60-minute

Table III. Conditions and Average Weight Changes

Series	Atropine	Walk	Temp		Hum		Wind-speed	Duration	Water added to suit	Gain in wt of suit	Nude wt loss	Clothed wt loss	Water intake
			Dry bulb	Wet bulb	Rel	Vapor pressure							
			°C		%	mm Hg	m/sec	hr	gm				
1	-	+	30	20	48	15	1.35	5	0	152	1212	1050	151
	+	+							0	44	865	821	438
2	-	+	30	20	48	15	0.05	3	0	590	1382	792	319
	+	+							0	410	964	554	243
3	-	+	30	26	80	25	0.05	3	0	1675	2191	516	984
	+	+							0	508	893	385	375
4	-	+	30	26	80	25	0.05	3	ca 1000	622	1288	666	262
	+	+							ca 1000	4	614	610	196
5	-	-	41	24	25	15	0.05	3	0	1124	1717	593	724
	+	-							0	560	1043	483	278
6	-	+	41	24	25	15	0.05	3*	ca 1000	1025	2027	1002	575
	+	+							ca 1000	9	876	867	308

*Subject K was removed after 2 hours in both experiments. Subject I was removed after 2 hours in the control experiment.

Table IV. Weight of Major Items of Clothing

Series	Undershirt	Underdrawers	Jacket	Trousers	Sum
		gm			
Series 3					
Before	411	391	597	584	1983
After	723	575	913	760	2971
Series 5					
Before	407	381	586	577	1951
After	687	520	840	676	2723
Series 6					
Before	399	394	595	580	1968
Plus water	843	921	600	585	2949
After	792	699	1007	820	3318

period, the reduction in E with atropine produced a significant increase in S in series 1, 2, and 5. During the 90-to 180-minute period, the effect of atropine on S was small, although in series 6 the slope was statistically significant. The slope of the regression of S on E in the 30- to 60-minute period changed from near unity in series 1 to near zero in series 3, while the water content of the clothing at the end of the test increased 10-fold (table III).

The water content of the clothing during the 30- to 60-minute period was not measured directly, but a rough approximation was made from the arm sweat data. Although the arm sweat is not necessarily an adequate sample of the whole body sweat, it is the only measure of the changes in sweating with time during the test. Estimates of the whole body sweat at 30 and 60 minutes were obtained by multiplying the nude weight loss by the fractions of arm sweat in 30 and in 60 minutes over the arm sweat for the entire test. The estimate of sweat produced minus the observed clothed weight loss thus gives a measure of the gain in weight of the clothing; the average between 30 and 60 minutes is an estimate of the average water content of the clothing for this period. Even with a large margin for error, the results in table VII suggest that the change in water content between series 1 and 3 was considerably less than was indicated by the water content at the end of the test from table I. The estimated water content for series 2 and 5 was intermediate between that for series 1 and 3, and all these were much less than in the wet clothing in series 4 and 6.

Comparison of series 3 and 4 reveals a substantial reduction in sweating associated with the initial wetting of the clothing (table III). The data of Robinson and Turrell[11] are shown in table VIII. Wetting the clothing reduced the skin temperature, as may be seen in figure 2 and table VIII.[11] In series 2, 3, 4, and 6, conditions were sufficiently similar to permit relating the sweat production and the body temperatures averaged over 3 hours. When plotted, the data for the wet and dry clothing conditions seem to fall along the same line. The regressions for the pooled data (without atropine) have highly significant slopes: the correlation is somewhat better for the skin temperatures than for the mean body temperature. With atropine the slopes are less steep (table IX).

IV. DISCUSSION.

For men wearing the CBR protective uniform, a 2-mg dose of atropine had only a marginal effect on rectal temperature when they remained at rest. This was demonstrated in series 5

[11] Robinson, S., and Turrell, E. S. Indiana University Medical School. First Interim Report. Contract OEM-cmr-351. Physiological Studies of Clothing for Men Working in Humid Heat. 7 December 1943. UNCLASSIFIED Report.

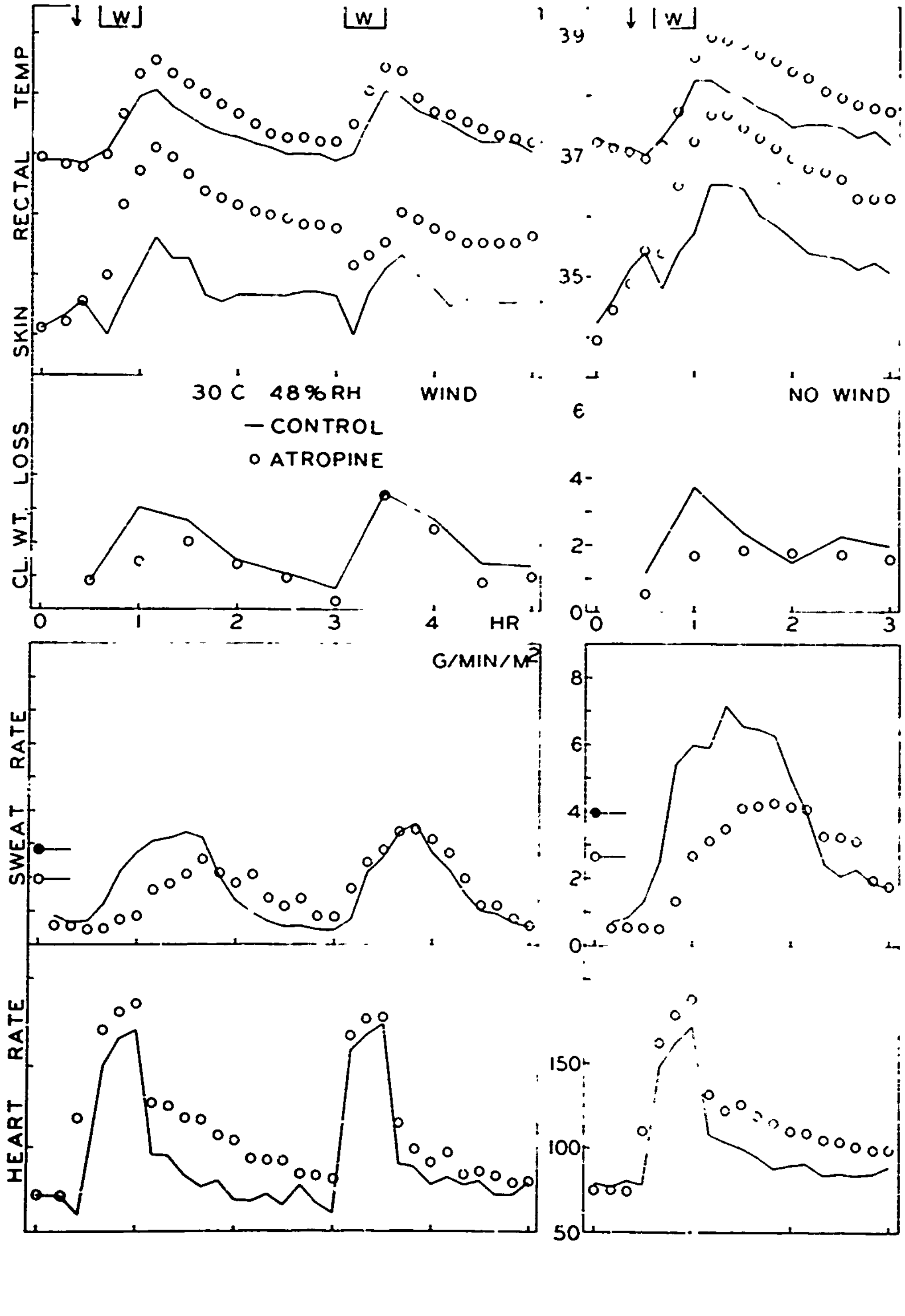

Figure 1. Average Results, Series 1 and 2

Initially dry clothing with and without wind. Clothed weight loss and arm sweat in grams per minute per square meter. The horizontal bar in the sweat rate panel indicates the average nude weight loss. The vertical arrow marks the time of injection of atropine. The inclosed W indicates the walk.

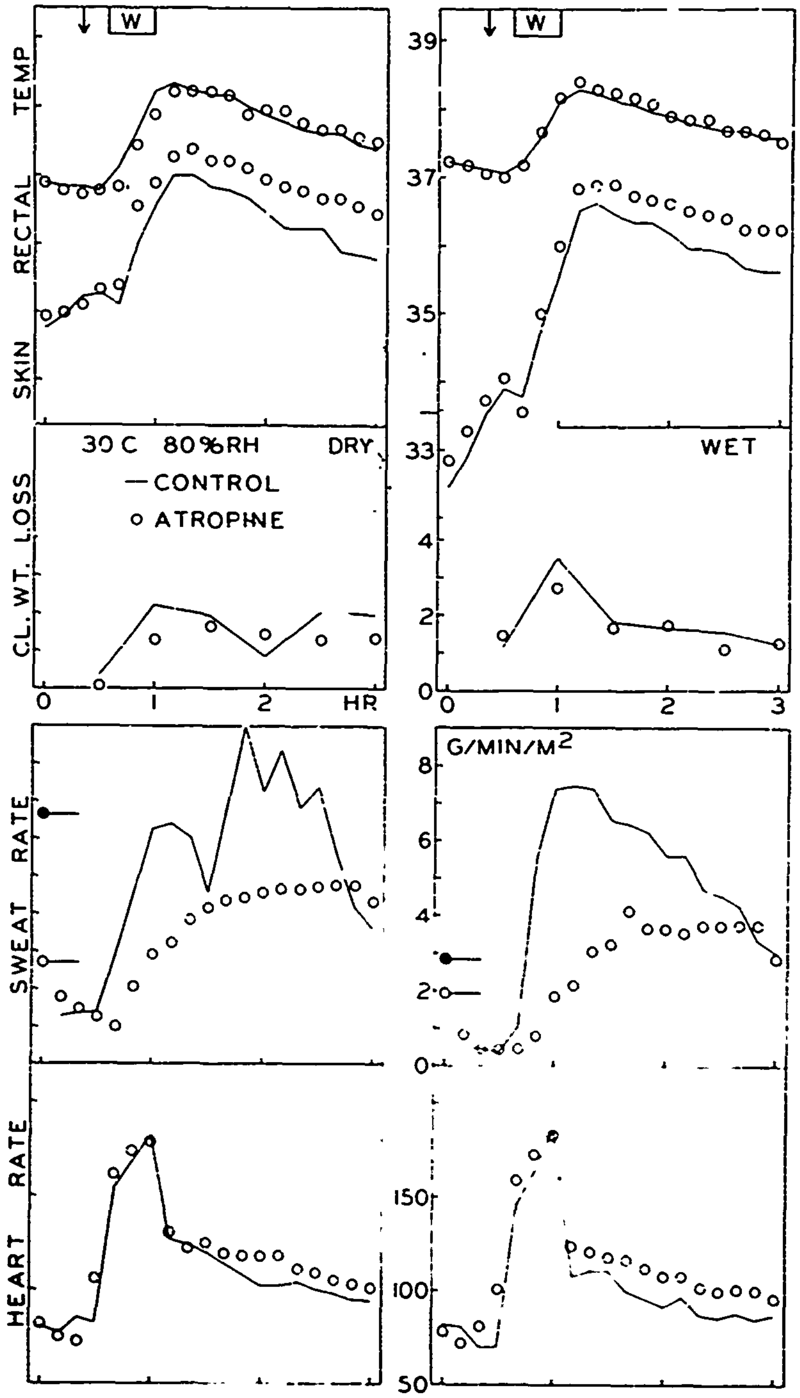

Figure 2. Average Results, Series 3 and 4

Initially dry and wet clothing without wind. Symbols as in figure 1.

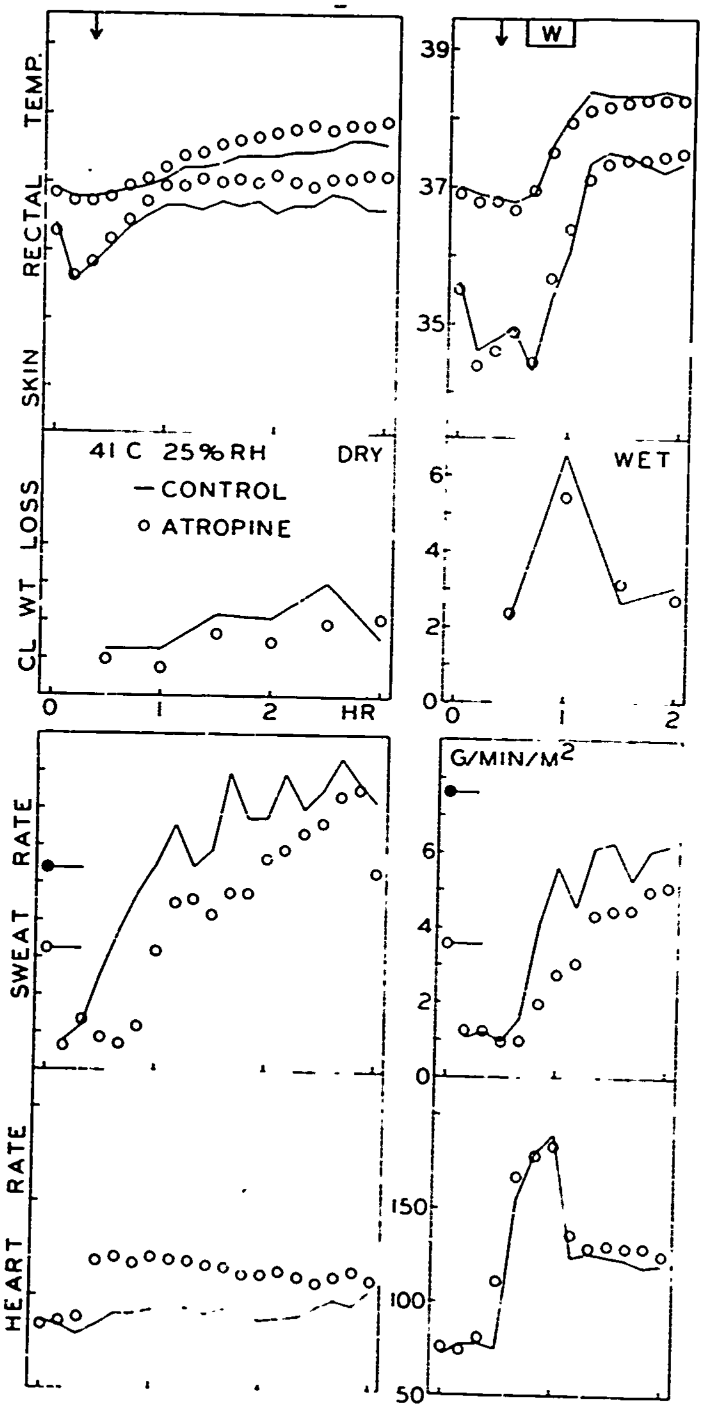

Figure 3. Average Results, Series 5 and 6

Initially dry clothing without walk in series 5; initially wet clothing with walk in series 6, both without wind. Symbols as in figure 1.

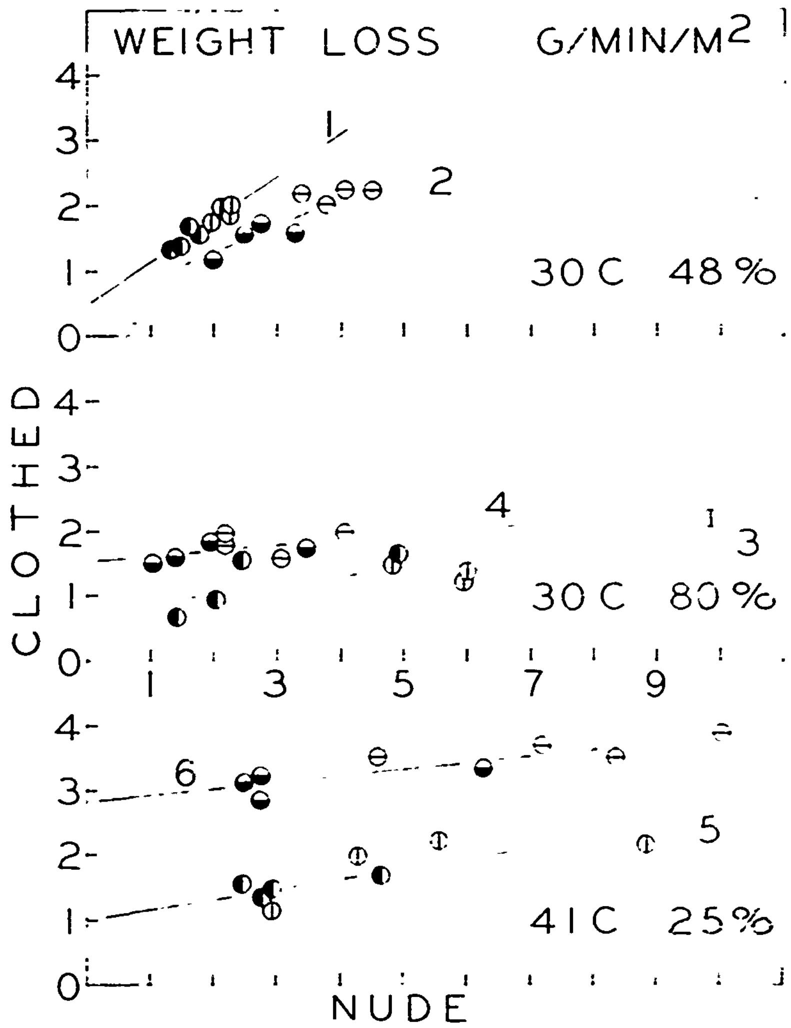

Figure 4. Clothed and Nude Weight Loss

Individual data for clothed and nude weight loss, odd series with vertical bars, even series with horizontal bars, atropine with half-filled circles.

in which the conditions resembled those of a hot, dry environment at night or in the shade. The condition would be equivalent to one with a dry bulb temperature 5°C lower in the presence of sunshine.[6] Series 1 and 2 illustrate what might be found in an environment like a hot desert to the extent that sweat does not accumulate in the clothing. The results indicate that after administration of atropine, a potentially dangerous increase in rectal temperature can be avoided by refraining from muscular work or by artificially wetting the clothing. In a humid tropical environment such as in series 3, it is likely the clothing usually would contain enough sweat to make additions of water to the clothing unnecessary.

The results suggest that even at a dose of 6 mg of atropine, the rectal temperature could be maintained within safe limits by wetting the clothing and avoiding muscular work. However, this needs to be tested experimentally.

Table V. Regressions of Clothed Weight Loss, y, on Nude Weight Loss, x, of the Form $y = a + bx$ From Eight Observations on Four Men

Series	a ±SE	b ±SE*	r
1	0.477 ±0.04	0.6487 ±0.099	0.937
2	0.470 ±0.08	0.4141 ±0.086	0.892
3	0.745 ±0.12	0.1353 ±0.040	0.813
4	1.534 ±0.07	0.0889 ±0.062	0.501
5	1.031 ±0.10	0.1528 ±0.044	0.816
6	2.837 ±0.07	0.0991 ±0.023	0.870

*Insignificant slope in series 4; slopes in other series significant at better than 99%.

The choice of the amount of water to add to the clothing in series 4 and 6 was based on experience with this assembly.[6] (At about 30°C either in sun or shade, the clothing gained about a kilogram in weight during 2 hours of walking at 3 mph on the level.) For the purpose of investigating the effectiveness of evaporative cooling, this represents an overload of the system. Storage was not increased by the temporary inhibition of sweating by atropine in series 3 when the water content of the clothing during the 30- to 60-minute period must have been much less than in series 4.

Although the slope of the regression of S on E provides a measure of the effectiveness of evaporative cooling, it refers to the effectiveness of an increment, for even at a slope of zero there must be some contribution of evaporative cooling to the heat exchange of the man inside the clothing. This measure is thus quite different from the Burton[7,8] factor derived from insulation values. The results, however, do suggest that the major change in the Burton factor will be found in a range of relatively small additions of water to the clothing.

From the relations between sweating and skin and mean body temperatures in table IX, it appears that cooling of the skin accounts for the reduction in sweating when the clothing was initially wet. More extensive suppression of sweating by cooling the skin has been described by Webb and Annis[12] and by Banerjee, Elizondo, and Bullard.[13]

With wet clothing, changing the environmental temperature from 30° to 41°C had little effect on heat storage during exercise. This is in agreement with Nielsen's[14,15] observations that the elevation in core temperature for a given rate of work is the same over a wide range of environmental temperatures. With dry clothing at 30°C, suppression of sweating by atropine increased the heat storage. Thus, Nielsen's concept of the regulation of core temperature by the work rate depends on an adequate sweat rate. As Lind[16] has shown, if the environmental temperature is too high, the sweat rate during exercise is unable to prevent a further rise in core

[12] Webb, P., and Annis, J. F. Cooling Required to Suppress Sweating During Work. J. Appl. Physiol. *25*, 489-493 (1968).

[13] Banerjee, M. R., Elizondo, R., and Bullard, R. W. Reflex Responses of Human Sweat Glands to Different Rates of Cooling. J. Appl. Physiol. *26*, 787-792 (1969).

[14] Nielsen, M. Die Regulation der Korpertemperatur bei Muskelarbeit. Skand. Arch. Physiol. *79*, 193-230 (1938).

[15] Nielsen, M. Heat Production and Body Temperature During Rest and Work. *In* Physiological and Behavioral Temperature Regulation. Ch 14. ed. J. D. Hardy, A. P. Gagge, and J. A. J. Stolwijk. Charles C. Thomas, Springfield, Illinois. 1970.

[16] Lind, A. R. A Physiological Criterion for Setting Thermal Environmental Limits. J. Appl. Physiol. *18*, 51-56 (1963).

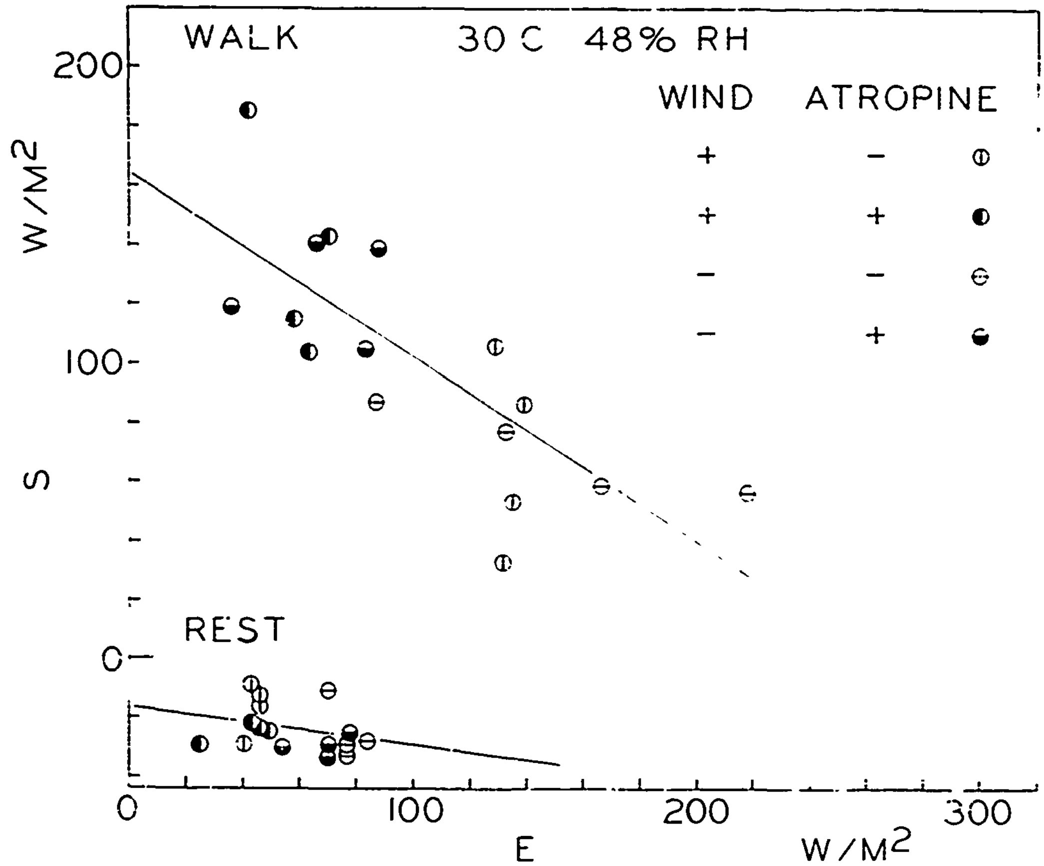

Figure 5. Storage and Heat of Evaporation, Series 1 and 2

Individual data for series 1 and 2. WALK designates the 30- to 60-minute period; REST designates the 90- to 180-minute period.

temperature.The experiments of Smiles and Robinson[17] suggest a change in emphasis: it is not core temperature that is regulated by work, but work and various body temperatures combine to regulate sweating.

V. CONCLUSIONS.

In troops wearing the CBR protective uniform who inject a 2-mg dose of atropine into themselves on the mistaken assumption of an exposure to an anticholinesterase agent, the rise in rectal temperature caused by inhibition of sweating by atropine can be kept within safe limits if exercise is avoided and the clothing is wet with sweat at the time of injection. In environments where sweat does not accumulate in the clothing, artificial wetting of the clothing would be required to compensate for the deficit in sweating.

In environments where sweat does not accumulate in the clothing, the deficit in evaporative heat loss associated with atropine is matched by an approximately equal gain in storage of heat in the body. When the clothing is wetted artificially or by the accumulation of sweat, the

[17]Smiles, K. A., and Robinson, S. Regulation of Sweat Secretion During Positive and Negative Work. J. Appl. Physiol. 30, 409-412 (1971).

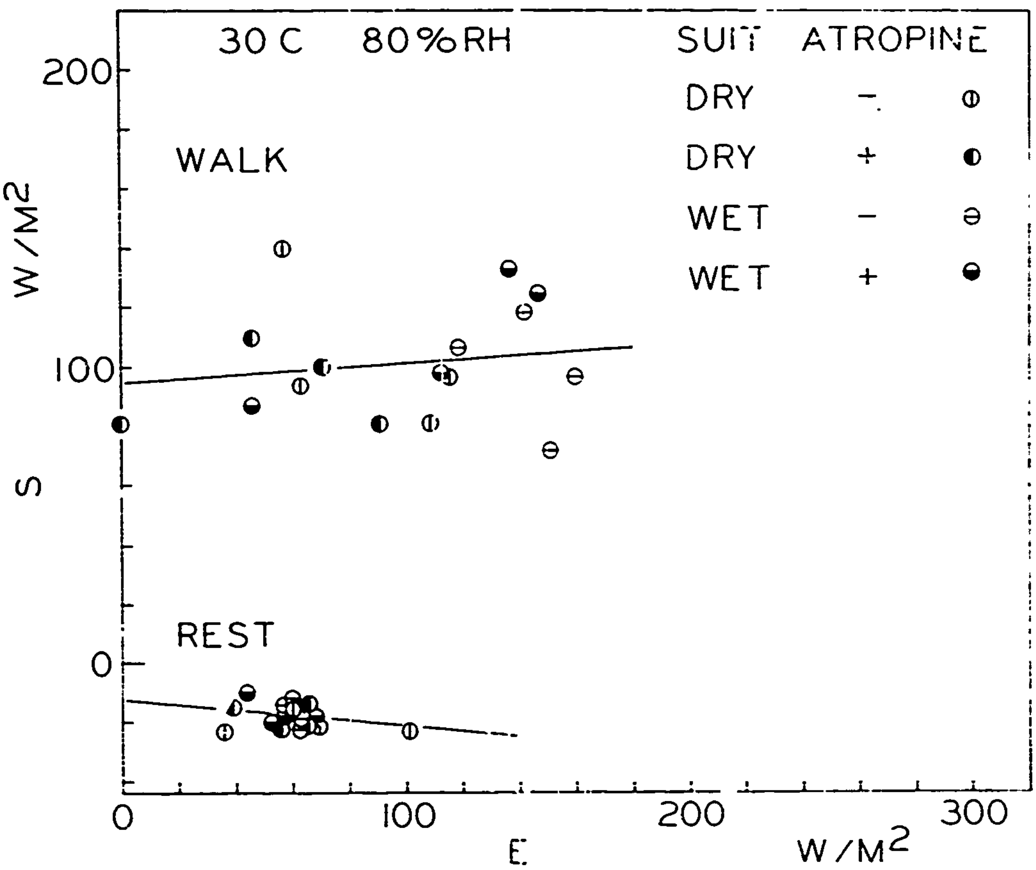

Figure 6. Storage and Heat of Evaporation, Series 3 and 4

Individual data for series 3 and 4. WALK designates the 30- to 60-minute period; REST designates the 90- to 180-minute period.

heat storage is not affected by the deficit in evaporative heat loss; thus, an increment in evaporation from wet clothing is less efficient in cooling the body than evaporation from the skin under dry clothing.

Sweating (nude weight loss) and evaporation from clothing (clothed weight loss) increase in proportion one to the other, but the fraction of sweat evaporated is less from wet than from dry clothing.

Sweat production during exposure to heat is substantially less when the clothing is initially wet with water. The reduction in sweating is attributed to the cooling of the skin by the wet clothing.

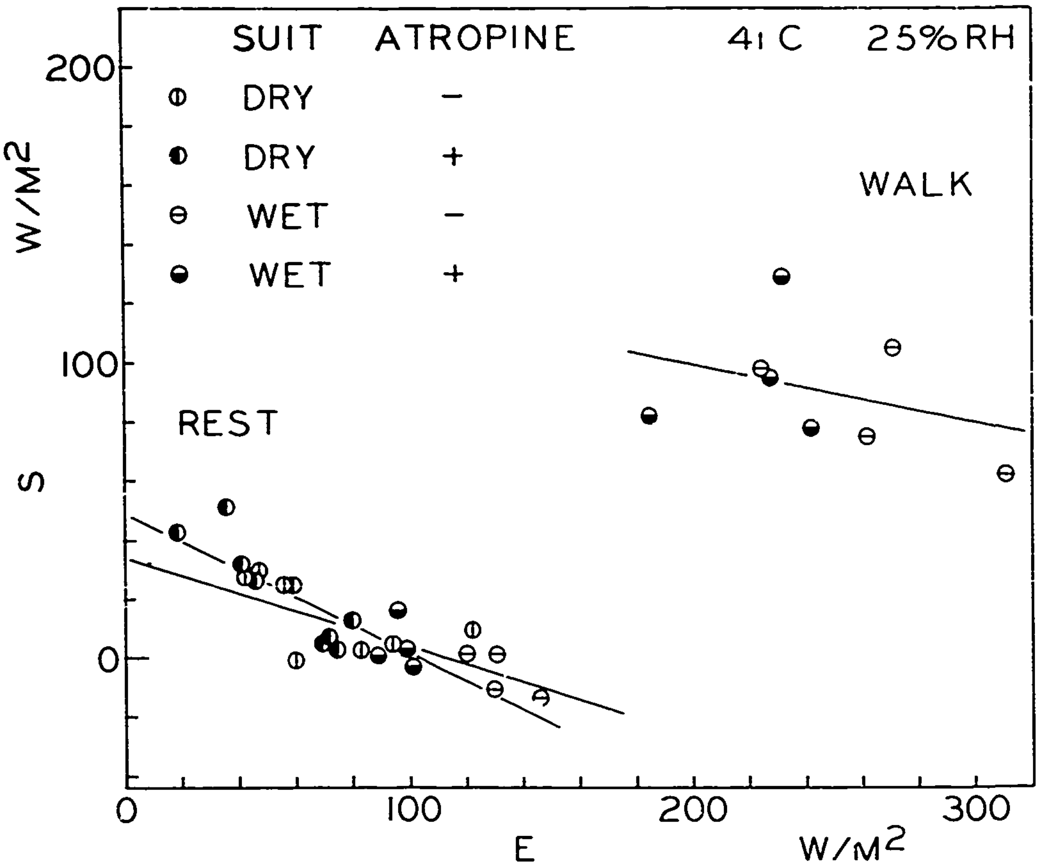

Figure 7. Storage and Heat of Evaporation, Series 5 and 6

Individual data for series 5 and 6. WALK designates the 30- to 60-minute period in series 6; REST designates the 90- to 180-minute period in series 6 with horizontal bars. In series 5 with vertical bars, both the 30- to 60- and the 90- to 180-minute periods are shown under REST, and the line represents the regression for the 16 points.

Table VI. Regressions of Heat Storage in W/sq m, y, on Heat of Evaporation in W/sq m, x, of the Form $y = a + bx$

Series	Walk	N	a ±SE	b ±SE	Sig	r
30-60-Min period						
1	+	8	193 ±13	-0.9315 ±0.29	99.1	-0.796
2	+	8	145 ±10	-0.4403 ±0.17	98.0	-0.731
1,2	+	16	164 ±7	-0.6089 ±0.14	99.9	-0.758
3	+	8	103 ±9	-0.0724 ±0.21	NS*	-0.136
4	+	8	85 ±9	0.1498 ±0.22	NS	0.265
3,4	+	16	95 ±5	0.0705 ±0.11	NS	0.164
5	–	8	58 ±3	-0.5808 ±0.20	98.6	-0.763
6	+	8	139 ±8	-0.1965 ±0.20	NS	-0.358
90-180-Min period						
1,2	–	16	17 ±2	0.1285 ±0.11	NS	0.289
3,4	–	16	12 ±1	0.0940 ±0.07	NS	0.336
5	–	8	- 4 ±2	0.1083 ±0.08	NS	0.484
6	–	8	34 ±3	-0.3040 ±0.13	96.9	-0.683
30-60- and 90-180-Min periods combined						
5	–	16	49 ±3	-0.4782 ±0.11	99.9	-0.768

*Not significant.

Table VII. Relation Between Efficiency of Evaporative Cooling and Water in Clothing in 30- to 60-Minute Period

Series	Regression slope[a]	Est water in clothing[b]	
		Without atropine	With atropine
		gm/sq m	
1	-0.93	-5	-21
2	-0.44	9	6
3	-0.07	107	27
4	0.15	ca 1000	ca 1000
5	-0.58	38	-4
6	-0.19	ca 1000	ca 1000

[a]From table VI.
[b]Average of estimates for 30 and 60 minutes from nude weight loss estimated from ratio of arm sweat for 30 to 60 minutes and the total arm sweat, less the clothed weight loss.

Table VIII. Data of Robinson and Turrell*

Subject SR. Conditions: 87°F, 80% RH, 0.25-mph wind, 3.5-mph walking speed, 2.5% grade, single-layer poplin suit, suit initially wet or dry.

Time	Weight loss				Temp			
	Nude		Clothed		Skin		Rectal	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
hr	*gm*				*°F*			
0					92.1	93.6	99.8	99.9
1	500	870	430	400	93.4	95.0	99.9	100.0
2	570	890	550	525	93.9	94.8	100.0	100.3
3	500	620	560	590	93.8	93.6	99.9	100.0

*Robinson, S., and Turrell, E. S. Indiana University Medical School. First Interim Report. Contract OEM-cmr-351. Physiological Studies of Clothing for Men Working in Humid Heat. 7 December 1943. UNCLASSIFIED Report.

Table IX. Sweat Production and Temperatures Averaged Over 3 Hours in Series 2, 3, 4, and 6

Regression of sweat production in grams/minute/square meter (y), on temperature in degrees Centigrade (x), of the form $y = a + bx$, $N = 16$.

Atropine	a ±SE	b ±SE	Sig	r
		x = Skin temp		
-	-112.29 ±0.48	3.2879 ±0.87	99.9	0.711
+	- 45.05 ±0.33	1.3190 ±0.70	96.0	0.451
		x = Mean body temp		
-	-189.24 ±0.53	5.2549 ±1.72	99.6	0.633
+	- 74.74 ±0.32	2.0797 ±0.95	97.7	0.507

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